CLAIMS

Method

1. Method for producing hydrogen from a hydrocarbon with high energy efficiency while releasing very low or zero levels of carbon dioxide and pollutants, said method comprising:

- (a) a step for using a flow of (pure or nearly pure) oxygen to oxidize a portion of the hydrocarbons and to supply the heat required to convert, using water vapor, at suitable temperatures, nearly all of the other portion of the hydrocarbons into hydrogen, carbon monoxide and carbon dioxide, so that the hydrogen production yield is thus improved, the mixture formed by the hydrogen, the carbon monoxide, the carbon dioxide, and the excess water vapor hereinafter being referred to as the products of the conversion, said method also comprising:

- (b) a step for preheating said hydrocarbons, said flow of oxygen and said water to be vaporized; said hydrocarbons, said flow of oxygen, and the water to be vaporized hereinafter being referred to as the reagents, said method also comprising the following steps:

- (c) steps for cooling the conversion products in order to recover a fraction of the thermal energy of said conversion products for the purpose of preheating said reagents and condensing (13) at least part of the water vapor contained in said conversion products, said method also comprising the following steps:

- (d) a step for recovering the hydrogen by extracting the hydrogen from the conversion products, either in order to consume it, or to store it for later consumption, said steps being performed at suitably high pressures above 30 bar, in order to:

- intensify the heat exchanges, and/or
- increase the compactness of the method, and/or
- promote the liquefaction of the carbon dioxide (14) by cooling, and/or
- promote the condensation (13) of the water vapor by cooling, and/or
- improve the overall efficiency.

2. Method according to claim 1, said method also comprising:

- (e) steps for the final conversion (11) of said carbon monoxide into carbon dioxide, if necessary during said step for recovering the hydrogen, so that at the end of steps (a) through (e), the residual flow no longer contains, apart from the water vapor that has not yet condensed, anything other than carbon dioxide.

3. Method according to claim 2, said method being performed at sufficient pressure to implement:

• (f) a step for condensing (14) said carbon dioxide contained in said conversion products and/or said final conversion products (11),

• a step for capturing said carbon dioxide in liquid form.

4. Method according to either of claims 2 and 3, said method using a membrane that is selectively permeable (26) to hydrogen to extract the hydrogen from the conversion products, said method also comprising:

- a step for lowering the partial pressure of the hydrogen downstream from said permeable membrane (26) by diluting the flow of permeated hydrogen in a flow of extraction gas (7), particularly a condensable gas, so that:

• the permeation of the hydrogen is facilitated,

• the recovery of pure hydrogen through condensation of the extraction gas is possible.

5. Method according to claims 2 and 4 taken together, said extraction (7) of hydrogen by means of a hydrogen-permeable membrane (26) being performed at the same time as said final conversion step (11), so that the partial pressure of the hydrogen during the final conversion step (11) is lowered, which promotes the conversion of the carbon monoxide into carbon dioxide.

6. Method according to claim 5, said method also comprising:

- a step for regulating the temperature of the final conversion (11) by adjusting the flow rate and/or the temperature of said flow of extraction gas (27).

7. Method according to any of claims 1 through 6, said method being such that said preheating and cooling steps are combined in a recovery exchanger so that said reagents and said conversion products circulate continuously through said recovery exchanger.

8. Method according to any of claims 1 through 7, said method being more specifically intended to produce hydrogen for the purpose of feeding a fuel cell (17) running with air, said method also comprising:

- a step for reducing the pressure (18) of said conversion products and/or said final conversion products (11) and/or the hydrogen produced while compressing the air required to run said fuel cell (17).

9. Method according to any of claims 1 through 8, said method also being combined with a hydrogen production method that generates a flow of oxygen, particularly by electrolysis, so that it is thus possible:

- to limit the cost of producing the oxygen consumed in the method according to the invention, and
- to increase the overall quantity of hydrogen produced.

10. Method according to any of claims 1 through 8, said method also being combined with a nitrogen production method that generates a flow of oxygen, so that it is thus possible to limit the cost of producing the oxygen consumed in the method according to the invention.

11. Device (1) for producing hydrogen from a hydrocarbon with high energy efficiency while releasing very low or zero levels of carbon dioxide and pollutants, said device (1) comprising:

- (a) a reactor for converting (4) said hydrocarbons using water vapor, said conversion reactor (4) being supplied with pure or nearly pure oxygen in order to oxidize a portion of the hydrocarbons and supply the heat required to convert into hydrogen, carbon monoxide and carbon dioxide, at suitable temperatures, nearly all of the other portion of the hydrocarbons, the mixture formed by the hydrogen, the carbon monoxide, the carbon dioxide and the excess

water vapor hereinafter being referred to as the products of the conversion, said device (1) also comprising:

- (b) means for preheating (5) said hydrocarbons, said flow of oxygen, and the water to be vaporized; said hydrocarbons, said flow of oxygen and the water to be vaporized hereinafter being referred to as the reagents, said device (1) also comprising:

- (c) at least one heat exchanger (6) for cooling said conversion products, for recycling a fraction of the thermal energy of said conversion products in order to preheat said reagents, and for condensing (13), at least a part of the water vapor contained in said conversion products,

- (d) a hydrogen recovery unit comprising an extraction element (7) for extracting the hydrogen from the conversion products on order to consume it in a hydrogen-consuming device, particularly a fuel cell, or store it in a hydrogen reservoir (10) for later consumption, said conversion reactor (4), said preheating means (5), said heat exchanger (6) and said recovery unit operating at suitably high pressures, above 30 bar, in order to:

- intensify the heat exchanges, and/or
- increase the compactness of the method, and/or
- promote the liquefaction of the carbon dioxide by cooling, and/or
- promote the condensation (13) of the water vapor by cooling, and/or
- improve the overall efficiency.

12. Device (1) according to claim 11, said device (1) also comprising

- (e) at least one reactor for the final conversion (11) of said carbon monoxide into carbon dioxide, if necessary combined with said hydrogen recovery unit, so that the residual flow that leaves said device (1) no longer contains, apart from the water vapor that has not yet condensed, anything other than said carbon dioxide.

13. Device (1) according to claim 12, the pressure inside said device (1) being sufficient to implement:

- a condenser (14) of said carbon dioxide contained in said conversion products and/or said final conversion products (11),
- a container for storing (15) said carbon dioxide in liquid form.

14. Device (1) according to any of claims 11 through 13, said extraction element (7) comprising a membrane (26) that is selectively permeable to hydrogen, for extracting the hydrogen from the conversion products, said extraction element (7) also comprising a feed of extraction gas (27), particularly an easily condensable gas, located downstream from said permeable membrane (26), which lowers the partial pressure of the hydrogen downstream from said permeable membrane (26) and diluting the flow of permeated hydrogen, so that:

- the permeation of the hydrogen is facilitated,
- the recovery of pure hydrogen through condensation of the extraction gas is possible.

15. Device (1) according to claims 12 and 14 taken together, said element for extraction (7) by means of a permeable membrane (26) being disposed inside the final conversion reactor (11), so that the partial pressure of the hydrogen during the final conversion (11) is lowered, which promotes the conversion of the carbon monoxide into carbon dioxide.

16. Device (1) according to claim 15, said device (1) also comprising means for regulating the temperature of the final conversion (11), by acting on the flow rate and/or the input temperature of the extraction gas (27).

17. Device (1) according to any of claims 15 or 16, said device (10) being such that said permeable membrane (26) is composed of a plurality of tubes that descend into said extraction element (7), each tube having the shape of a glove finger whose open end opens to the outside of said extraction element (7), said open end making it possible to introduce said extraction gas (27) into said tube.

18. Device (1) according to any of claims 11 through 17, said device (1) being such that said preheating means (5) and said cooling heat exchanger (6) are combined in a recovery exchanger so that said reagents and said conversion products circulate continuously through said recovery exchanger.

19. Device (1) according to any of claims 11 through 18, said device (1) being more specifically intended to produce hydrogen for the purpose of feeding a fuel cell (17) running with air, said device (1) also comprising an element for lowering the pressure (18) of said conversion products and/or said final conversion products (11) and/or the hydrogen produced, making it possible to compress the air required to run said fuel cell (17).

20. Device (1) according to any of claims 11 through 19, said device (1) also being combined with a hydrogen production unit that generates a flow of oxygen, particularly through an electrolyzer.

21. Device (1) according to any of claims 11 through 19, said device (1) also being combined with a nitrogen production unit that generates a flow of oxygen, so that it is thus possible to limit the cost of producing the oxygen consumed in the method according to the invention.